Military Operations Research Society

73rd MORSS CD Cover Page

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Name of Principal Author and all other author(s): Jeffrey R. Cares

Principal Author's Organization and address:
Alidade Incorporated
31 Bridge Street
Newport, RI 02840

Phone:_401-367-0040_____________

Fax:___401-633-6420_____________

Email:__jeff.cares@alidade.net_____

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Decision Analysis, Distributed Forces and Complex Causality

Jeffrey R. Cares

73rd MORSS

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Complex Causality

Introduction

- Distributed, networked systems are "complex systems"
- Complex Causality and distributed, networked systems
  - Even if desired effects (e.g., performance goals) are provided, methods to achieve them may be elusive
  - Control will be questionable
- Complex Causality and NCW/IAW MOEs
  - We cannot be sure that our measures actually measure effectiveness, because we cannot trace improvements in inputs to improvements in outcomes.

Combat Model Potential Complexity

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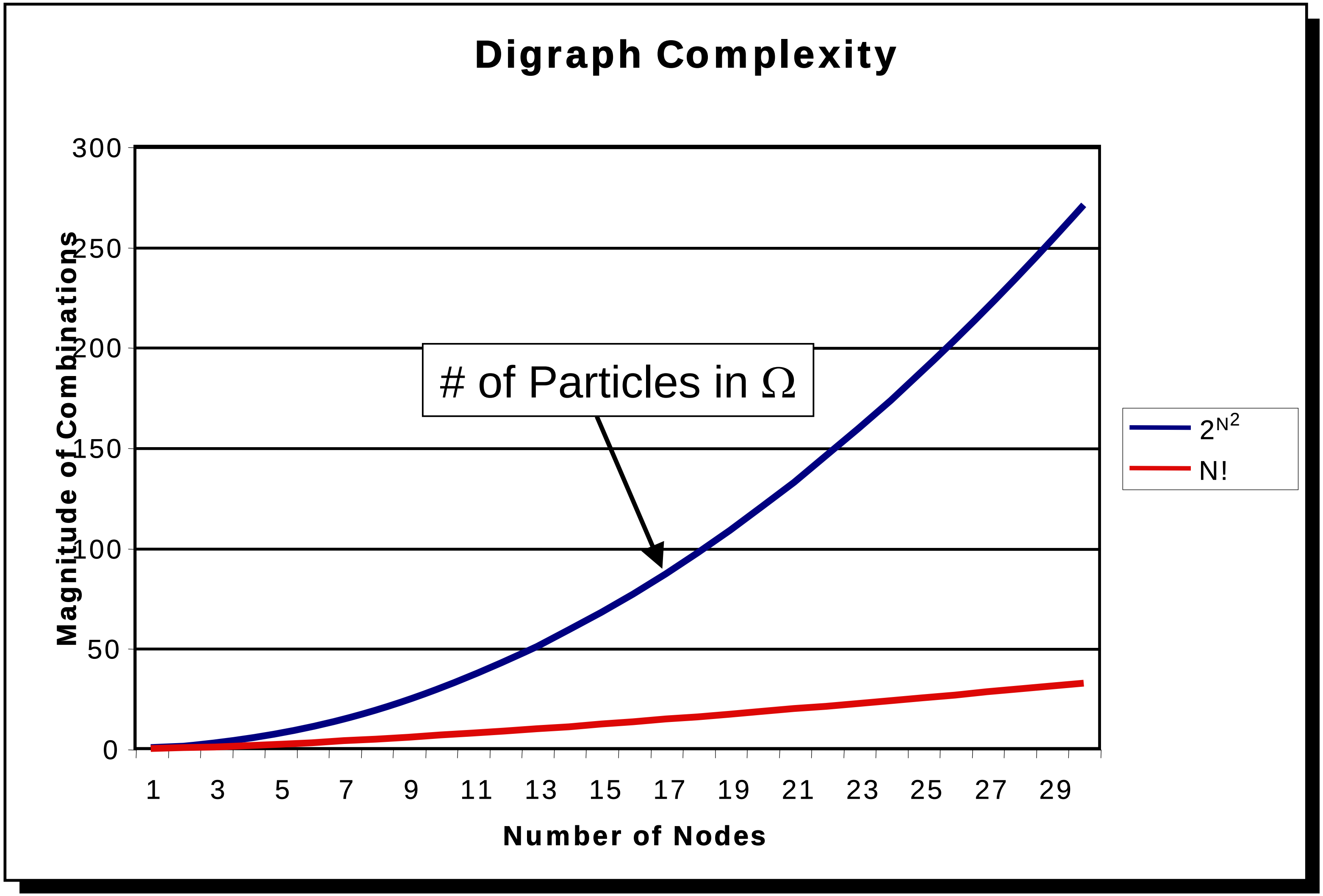
Complex Causality



Synchronization Continuum

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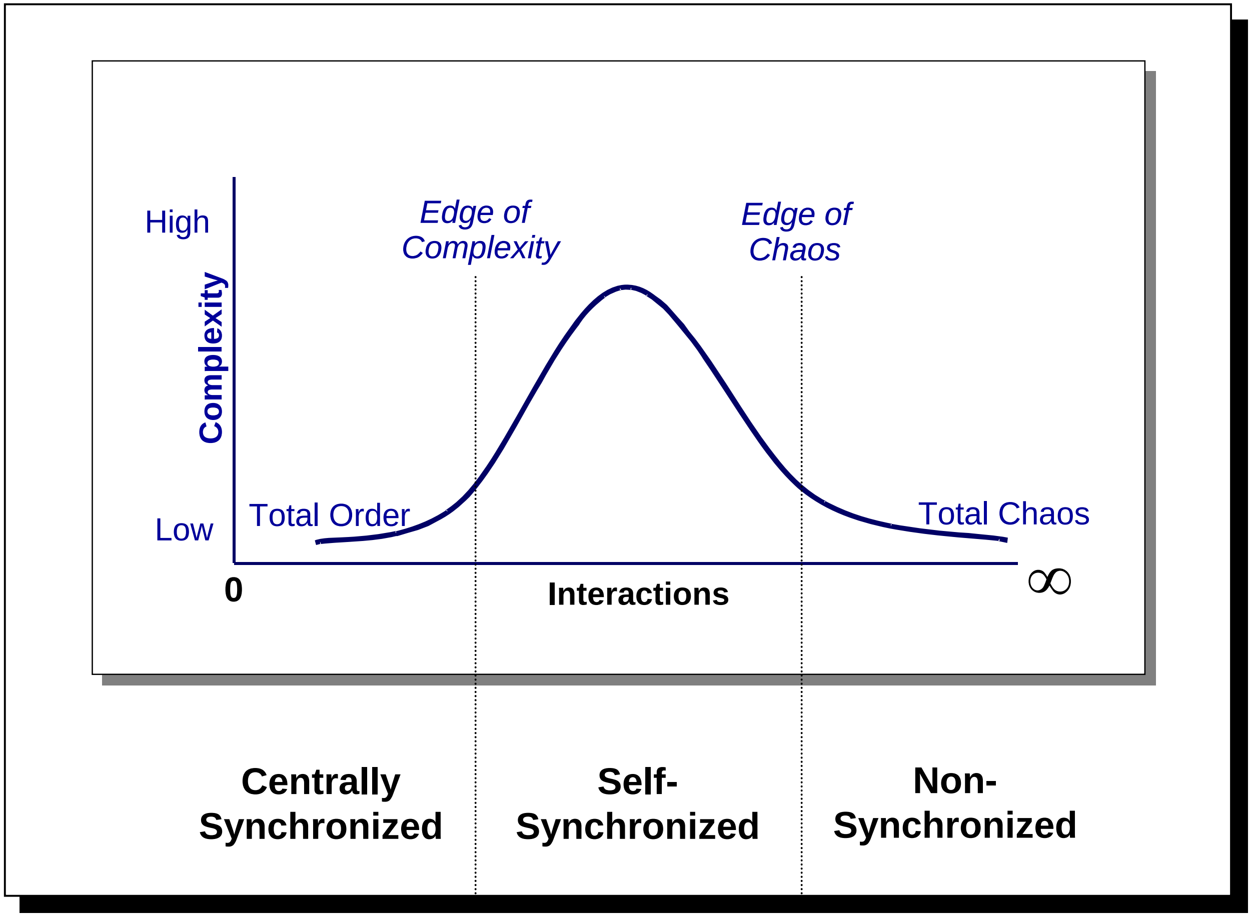
Complex Causality



Each extreme is rare; most real cases are likely in the middle (that is, partly centrally synchronized and partly non-synchronized)

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Complex Causality

"Simple" Causality

- Hume (1748)
  - A notion fundamental to human cognition
  - Basic idea, necessary and sufficient conditions
- Russell (1913)
  - Functional relationships among state variables of a system
- Suppes (1970)
  - "Probabilistic Causality": reaction to Quantum Mechanics
  - Causes raise the probability of their effects
- Mackie (1974)
  - INUS Conditions: Insufficient but non-redundant part of an unnecessary but sufficient condition
  - e.g., A lit match can cause a forest fire but not all lit matches cause forest fires

Causality is well-defined for deterministic and stochastic linear and chaotic systems

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Complex Causality

Simple Deterministic Causality

Requires "regularity" and *ceteris paribus* (among other constraints)

$y = \mathrm{m}{\bullet}x + \mathrm{b}$

$\mathrm{m} = 1, \mathrm{b} = 1$

If $x = 1, y = 2$
If $x = 2, y = 3$
If $x = 3, y = 4$
If $x = 4, y = 5$

…..

- Regularity: The operators =, •, and + have consistent meaning and the result behaves in a "regular" way
- *Ceteris Parabus*: Fixing all other variables results in a cause always being followed by the same effect
- Separability: b can be ignored in a description of the behavior

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Simple Probabilistic Causality

Complex Causality

Requires "regularity" and *ceteris paribus* (among other constraints)

A causes B iff:

P(B|A) > P(B|not-A)

- **Regularity, *Ceteris Parabus,* Separability still pertain**
- **Asymmetry and spurious correlations are issues**
- **Biggest problem: *Reductive analysis* is not possible possible. In fact, there is no theory that details the systemic connections between causation and probability**

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Complex Causality

Complex Causality

- Wagner (1997)
  - The notion of regularity does not hold for non-linear, complex systems
  - The effect depends on the context
- Hohler and Gumerman (2000)
  - New notion of causal regularity
    - Regularity exists because of the behavioral and cognitive linkages between context and action at the level of the agents
  - "Dual Status" of variables as outcomes of behavior and as contexts for behavior
- Barwise, Seligman (1997)
  - Information flow is a result of regularities in distributed systems
- Pearl, et al (1998+)
  - Structural Equation Models and complex causes
- Crutchfield and Shalizi (1999+)
  - Computational Mechanics: initial results in prediction, pattern discovery, causality in complex systems

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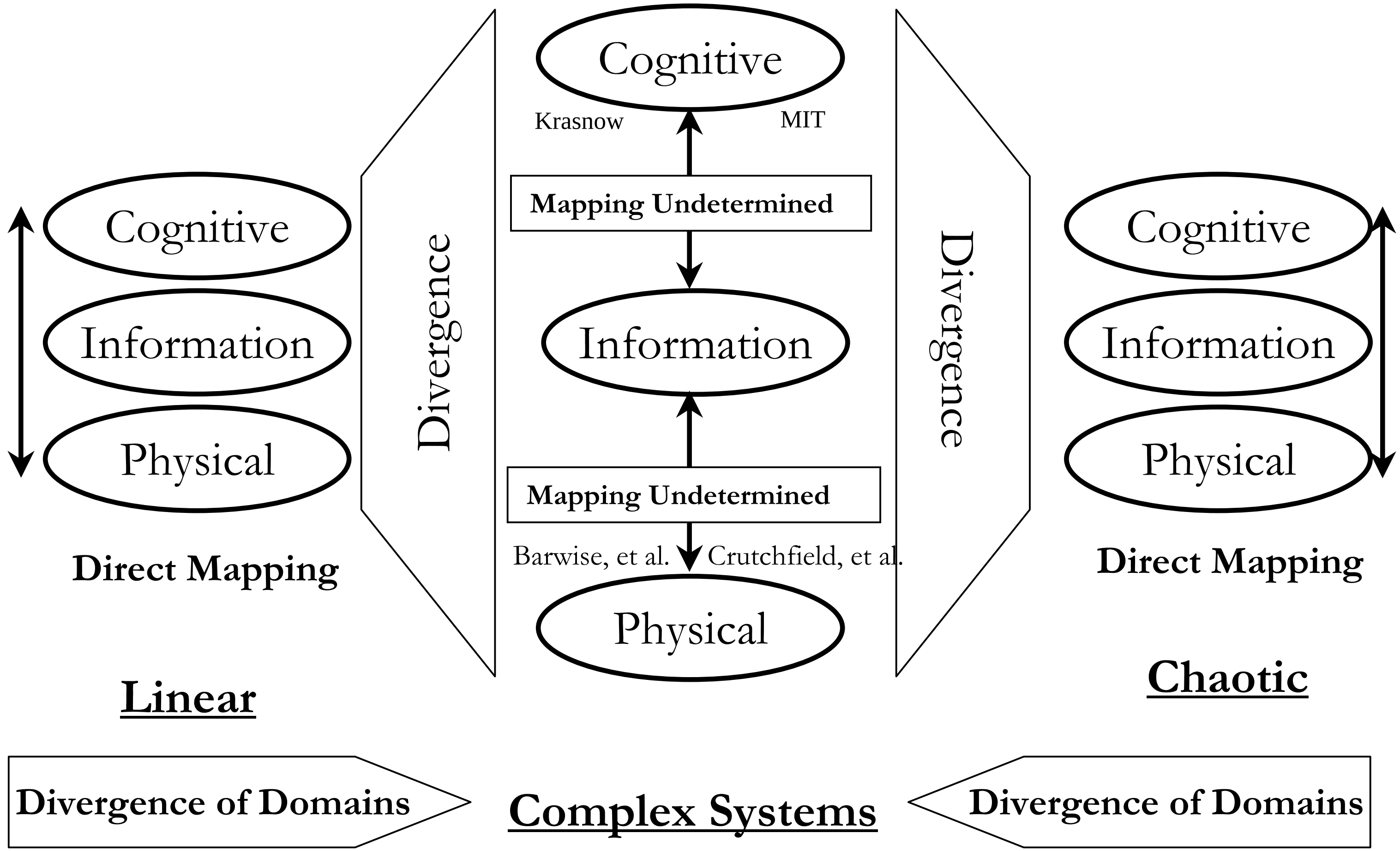
Complex Causality

Complex Causality

A Research Frontier



Conclusions

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Complex Causality

- There are no tools for determining complex causality
- Brute Force approaches exist
- Fundamental research has recently started (including genomics research)
- New visions of NCW, EBO and IAW are built on a base of sand
  - Hopefully, this condition is temporary

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Complex Systems Research

Process Innovation & Analysis

Strategic Investment Advice

Future Concept Generation

Corporate/Government War Games & Events

Questions?